Psychological and Physiological Acoustics
Session 2pPPb: Speech, Attention, and Impairment (Poster Session)

2pPPb17. The role of peripheral spectro-temporal coding in congenital amusia
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Congenital amusia, a neurogenetic disorder, affects primarily pitch and melody perception. Here we test the hypothesis that amusics suffer from impaired access to spectro-temporal fine-structure cues associated with low-order resolved harmonics. The hypothesis is motivated by the fact that tones containing only unresolved harmonics result in poorer pitch sensitivity in normal-hearing listeners. F0DLs were measured in amusics and matched controls for harmonic complexes containing either resolved or unresolved harmonics. Sensitivity to temporal-fine-structure was assessed via interaural-time-difference (ITD) thresholds, intensity resolution was probed via interaural-level-difference (ILD) thresholds and intensity difference limens, and spectral resolution was estimated using the notched-noise method. As expected, F0DLs were elevated in amusics for resolved harmonics; however, no difference between amusics and controls was found for F0DLs using unresolved harmonics. The deficit appears unlikely to be due to temporal-fine-structure coding, as ITD thresholds were unimpaired in the amusic group. In addition, no differences were found between the two groups in ILD thresholds, intensity difference limens, or auditory-filter bandwidths. Overall the results suggest a pitch-specific deficit in fine spectro-temporal information processing in amusia that cannot be ascribed to defective temporal-fine-structure or spectral encoding in the auditory periphery. [Supported by Fyssen Foundation, Erasmus Mundus, CIHR, and NIH grant R01DC052166.]

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INTRODUCTION

Congenital amusia is a neurogenetic disorder that is characterized by a deficit in music perception and production that cannot be ascribed to hearing loss or intellectual deficiencies (Ayotte et al., 2002). These musical impairments are thought to pertain to a defective processing or encoding of pitch: poor familiar tune recognition, poor melody perception and elevated thresholds have been repeatedly observed in congenital amusics (Ayotte et al., 2002; Foxton et al., 2004; Hyde and Peretz, 2004). With the idea of being as close as possible to natural music listening situations when investigating the music perception deficit in amusics, most studies have been conducted with natural instrumental or voice sounds that contain full harmonic series.

Here we tested the hypothesis that the pitch perception deficits observed in congenital amusia rely on an inability to use spectro-temporal fine-structure cues associated with low-order resolved harmonics. This idea is motivated by the observation that the classic deficits found in amusia (impaired pitch thresholds and melody perception) can also be observed in normal listeners when the access to these cues is reduced by filtering out resolved harmonics (Moore and Rosen, 1979; Shackleton and Carlyon, 1994; Kaernbach and Bering, 2001).

Additionally, in studies on congenital amusia, amusics and control subjects either all have normal hearing or are matched in terms of audiogram. There is however recent evidence that normal audiogram is not enough to guarantee robust encoding of supra-threshold features (Ruggles et al., 2011) and that absolute hearing thresholds are not a good indicator of the integrity of frequency selectivity or encoding of temporal fine-structure cues (Strelcyk and Dau, 2009). It thus cannot be excluded from existing data that the observed deficits in congenital amusia stem from a peripheral encoding deficit.

In the present study, we took a psychoacoustical approach and assessed basic abilities in congenital amusics ranging from pitch and loudness perception to sensitivity to temporal fine-structure and spectral resolution.

METHODS

Eight amusics and eight matched controls participated in this study. They were tested in a sound-attenuating booth and sounds were delivered via headphones. The two groups did not differ significantly in age, education, music education or mean audiometric threshold.

Experiment 1: Difference limens were measured with the dual-pair task using a 2-up/1-down adaptive method using geometric step sizes in three different conditions: resolved pitch (P_R), unresolved pitch (P_U) and loudness (L). The sounds were harmonic complex tones, band-pass filtered between 1500 and 3500 Hz. The reference F0 was 250 Hz in the P_R condition, and 62.5 Hz in the P_U condition. The tones were mixed with pink noise in all conditions and the overall level of the noise was set at 6 dB below the overall level of the tones. The overall level of the tone plus noise compound was set close to 65 dB SPL. The stimuli from the P_R condition were also used in the L condition where the overall intensity was varied. On each trial, the reference in one of the pairs was roved up (higher in frequency or amplitude) by 20%. Each sound was 350 ms long and the two pairs were separated by a 500 ms silent delay. Subjects completed two runs in each condition and the best (smaller) was kept as the final estimate of threshold.

Experiment 2: Difference limens were measured for interaural-time differences (ITD) and interaural-level differences (ILD) using a 2I-2AFC task and a 3-down/1-up adaptive method using geometric steps. On each trial subjects were presented with two consecutive lowpass-filtered noises (cut-off frequency of 1000 Hz). These noises each comprised four segments of 250 ms each that were ramped on and off with 50-ms raised-cosine ramps, and no silent interval between the four segments. In the “reference” interval, there were no interaural differences in any of the four segments; in the “signal” interval, an ITD or ILD was introduced, which was reversed between alternating noises, producing a sensation of moving back and forth between left and right. Subjects completed two runs in each condition and the best (smaller) was kept as the final estimation of the threshold.

Experiment 3: Estimations of the auditory filter bandwidth at 2kHz were obtained in a 2I-2AFC using the notched-noise method. On each trial, subjects were presented with two consecutive noises, in one of which the signal was embedded. The noises were 700 ms long and were ramped on and off with 10-ms cosine ramps. The 2-kHz signal was 500 ms long and ramped on and off with 30-ms cosine ramps. The signal started 100 ms after and finished 100 ms before the noise in which it was embedded. Detection thresholds for the tone in noise were measured with three different width of symmetric notches, centered at 2kHz, with total widths of 0, 0.4f_o, and 0.8f_o.
where $f_0$ is the signal frequency. The signal had a fixed level of 45 dB SPL and the level of the noise masker was varied using a 3-up/1-down adaptive method. The tone and the masker were presented diotically.

**RESULTS AND DISCUSSION**

Consistent with existing reports of elevated thresholds in amusics with natural sounds, we found significantly poorer thresholds in amusics than in controls in the P_R condition. Of all experiments and conditions, P_R was the only condition where we found significant differences between the two groups. Thresholds were similar in the P_U condition, suggesting that amusics can make use of the temporal cues that are present in unresolved stimuli as well as controls do. Intensity resolution was also found to be similar between the two groups, as probed by L or ILD difference limens. Similar ITD thresholds revealed comparable processing of temporal fine-structure cues in the two populations. And finally, spectral resolution, as estimated using the notched-noise method, was also similar between the two populations.

The deficit in the processing of resolved harmonics could be the root of higher-order deficits such as those observed for melody perception. It could also explain the recently reported impaired harmonicity perception in congenital amusics (Cousineau et al., 2012). From the present data, we can also conclude that the cues to pitch provided by resolved harmonics, whether coded in a spectral or a temporal way are present in the peripheral auditory system of congenital amusics. The inability to make use of these cues must thus arise at a higher level in the auditory system. To fully understand the neuro-functional origin of the pitch deficit in amusia, additional studies will be needed to bridge the gap between the normal peripheral encoding reported here and anatomical and functional abnormalities reported at the cortical level (Hyde et al., 2007; Loui et al., 2009; Hyde et al., 2011)

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